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Číslo 1

Irem Sarbat & Seren Ozmehmet Tasan. *Ergonomics indicators: A proposal for sustainable process performance measurement in ergonomics*. Pages: 3-38.

Process performance measurement (PPM) has become a challenging task for organisations, which have many various processes, in today's globalised world. This challenging task is also remarkable in ergonomics, and combining sustainability with ergonomics can provide beneficial solutions for assessing risks and providing ergonomically favourable conditions for human well-being. In this paper, new ergonomics indicators (EIs) are proposed, classified, and described in detail to overcome this challenge through a systematic literature review that integrates ergonomics and sustainability. By considering sustainability indicators (SIs) selected from the review, the proposed EIs are presented within a three-dimensional structure. This structure enables measuring the performance on various issues in an organisation such as occupational health and safety, decent work, technology, working conditions, employee empowerment and development, charities, innovations, and recycling. Through systematic measurements using these indicators, more traceable and manageable processes can be achieved. Hence, ergonomists or managers can identify and prevent risky conditions practically. **Practitioner Summary:** This paper proposes ergonomics indicators and detailed descriptions for ensuring sustainable process performance measurement in ergonomics. The sustainability indicators presented as references for these proposals are utilised through selection and consolidation from literature. The ergonomics indicators are structured within a sustainability framework that considers six sustainability sub-dimensions proposed for ergonomics.

- **Keywords:** Ergonomics indicators, sustainability indicators, integration, lagging leading indicators, process performance measurement

Christopher J. Parker, Simeon Gill, Adrian Harwood, Steven G. Hayes & Maryam Ahmed. *A method for increasing 3D body scanning's precision: Gryphon and consecutive scanning*. Pages: 39-59.

The fashion industry cannot use 3 D Body Scanning to create custom garment patterns because its measurements fail to meet ISO 20685:2010's tolerances. To advance 3 D

Body Scanning's precision, we present Gryphon: an algorithm that removes the two most extreme measurements from five body scans; removing potentially erroneous data. We assess Gryphon's precision against current industry practice, determine if consecutive and non-consecutive data capture influences precision, and determine 3 D Body Scanning's inherent imprecision inherent. We analyse 97 participants over 121 industry-standard measurements for consecutive and non-consecutive data-capture through MANOVA statistical analysis. Under current industry practice, only one measurement meets ISO 20685. However, under Gryphon and consecutive scanning, 97.5% of measurements meet ISO 20685. We also prove that the body's in-scan movement does not affect reliability. Ultimately, we offer the fashion industry, ergonomists, and practitioners an accessible method to increase 3 D Body Scanning's precision at a level unavailable under previous methods. **Practitioner Summary:** Ergonomists need precise data, yet we prove 0% of 3 D Body Scanning's measurements meet ISO 20685's tolerances. Our analysis of 97 participants scans, shows consecutive scanning is necessary to achieve data suitable for anthropometric applications. We develop the Gryphon process with consecutive scanning, making 97.3% of measurements meet ISO 20685.

- **Keywords:** 3D body scanning, precision, measurement, anthropometrics, reliability

Cheng Chi, Xianyi Zeng, Pascal Bruniaux & Guillaume Tartare. *A study on segmentation and refinement of key human body parts by integrating manual measurements*. Pages: 60-77.

Optimal ergonomic design for consumer goods (such as garments and furniture) cannot be perfectly realised because of imprecise interactions between products and human models. In this paper, we propose a new body classification method that integrates human skeleton features, expert experience, manual measurement methods, and statistical analysis (principal component analysis and K-means clustering). Taking the upper body of young males as an example, the proposed method enables the classification of upper bodies into a number of levels at three key body segments (the arm root [seven levels], the shoulder [five levels], and the torso [below the shoulder, eight levels]). From several experiments, we found that the proposed method can lead to more accurate results than the classical classification methods based on three-dimensional (3 D) human model and can provide semantic knowledge of human body shapes. This includes interpretations of the classification results at these three body segments and key feature point positions, as determined by skeleton features and expert experience. Quantitative analysis also demonstrates that the reconstruction errors satisfy the requirements of garment design and production. **Practitioner summary** The acquisition and classification of anthropometric data constitute the basis of ergonomic design. This paper presents a new method for body classification that leads to more accurate results than classical classification methods (which are based on human body models). We also provide semantic knowledge about the shape of human body. The proposed method can also be extended to 3 D body modelling and to the design of other consumer products, such as furniture, seats, and cars.

- **Keywords:** Male upper body, body segmentation, body classification, manual anthropometry, semantic knowledge

Adam J. Reiner, Holland M. Vasquez, Greg A. Jamieson & Justin G. Hollands. *Comparing an augmented reality navigation display to an electronic map for military reconnaissance*. Pages: 78-90.

The next generation of displays for soldiers may include augmented reality capabilities. One such display, called Mirror in the Sky (MitS), presents survey information in the upper visual field. Using a virtual reality simulation of a military reconnaissance scenario,

we compared a MitS prototype to a familiar electronic 2D north-up map. Participants (24 soldiers) were told to follow a prescribed route, detect potential threats, and reroute around them. They also performed a secondary task as a measure of mental workload. At the end of the route, the soldiers were asked to recall the locations of threats and route changes. Participants made better reroute decisions with the north-up map than with MitS, although no differences were observed for threat detection or mental workload. They also scored higher on recall with the north-up map than with MitS. **Practitioner Summary:** An augmented reality navigation aid was compared to an electronic north-up map in a military reconnaissance scenario, in a virtual reality simulation. Participants made better route decisions and had better recall with the north-up map, but no mental workload differences were found between displays.

- **Keywords:** Navigation, augmented reality, virtual environments, workload, military

Maryam Zahabi, Farzaneh Shahini, Wei Yin & Xudong Zhang. *Physical and cognitive demands associated with police in-vehicle technology use: an on-road case study*. Pages: 91-104.

Motor vehicle crashes are a leading cause of police officers' deaths in line of duty. These crashes have been mainly attributed to officers' driving distraction caused by the use of in-vehicle technologies while driving. This paper presents a 3-h ride-along study of 20 police officers to assess the physical and cognitive demands associated with using in-vehicle technologies. The findings suggested that the mobile computer terminal (MCT) was the most frequently used in-vehicle system for the officers. In addition, officers perceived the MCT to significantly increase their visual, cognitive, and physical demands compared to other in-vehicle technologies. Evidence from electromyography and eye-tracking measures suggested that officers with more experience as a patrol officer and those who were working in more congested areas experienced higher cognitive workload. Furthermore, it was found that as the ride-along duration increased, there were indications of muscle fatigue in medial deltoid and triceps brachii muscles. **Practitioner summary:** This study assessed the impact of police in-vehicle technology use in an on-road case study. The findings provide new data and knowledge for police agencies and vehicle manufacturers to develop administrative measures and in-vehicle technology innovations to improve police officers' health and safety.

- **Keywords:** Cognitive load, driving, in-vehicle technology, physical load, police

Eric B. Weston, Mina Alizadeh, Hamed Hani, Gregory G. Knapik, Reid A. Souchereau & William S. Marras. *A physiological and biomechanical investigation of three passive upper-extremity exoskeletons during simulated overhead work*. Pages: 105-117.

The objective of this study was to evaluate three passive upper-extremity exoskeletons relative to a control condition. Twelve subjects performed an hour-long, simulated occupational task in a laboratory setting. Independent measures of exoskeleton, exertion height (overhead, head height), time, and their interactions were assessed. Dependent measures included changes in tissue oxygenation (ΔTSI) in the anterior deltoid and middle trapezius, peak resultant lumbar spine loading, and subjective discomfort in various body regions. A statistically significant reduction in ΔTSI between exoskeleton and control was only observed in one instance. Additionally, neither increases in spinal loading nor increases in subjective discomfort ratings were observed for any of the exoskeletons. Ultimately, the exoskeletons offered little to no physiological benefit for the conditions tested. However, the experimental task was not highly fatiguing to the subjects, denoted by low ΔTSI values across conditions. Results may vary for tasks requiring constant arm elevation or higher force demands. **Practitioner summary** This

study quantified the benefits of upper-extremity exoskeletons using NIRS, complementary to prior studies using EMG. The exoskeletons offered little to no physiological benefit for the conditions tested. However, the experimental task was not highly fatiguing, and results may vary for an experimental task with greater demand on the shoulders.

- **Keywords:** Tissue saturation index, exosuit, NIRS, wearable

Etienne Goubault, Romain Martinez, Jason Bouffard, Jennifer Dowling-Medley, Mickaël Begon & Fabien Dal Maso. *Shoulder electromyography-based indicators to assess manifestation of muscle fatigue during laboratory-simulated manual handling task*. Pages: 118-133.

Muscle fatigue is a risk factor for developing shoulder musculoskeletal disorders. The aim of this study was to identify shoulder electromyographic indicators that are most indicative of muscle fatigue during a laboratory simulated manual handling task. Thirty-two participants were equipped with electromyographic electrodes on 10 shoulder muscles and moved boxes for 45-minutes. The modified rate of perceived exertion (mRPE) was assessed every 5-minutes and multivariate linear regressions were performed between myoelectric manifestation of fatigue (MMF) and the mRPE scores. During a manual handling task representative of industry working conditions, *spectral entropy*, *median frequency*, and *mobility* were the electromyographic indicators that explained the largest percentage of the mRPE. Overall, the deltoids, biceps and upper trapezius were the muscles that most often showed significant changes over time in their electromyographic indicators. The combination of these three indicators may improve the accuracy for the assessment of MMF during manual handling. **Practitioner Summary:** To date, muscle fatigue has primarily been assessed during tasks done to exhaustion, which are not representative of typical working conditions. During a manual handling task representative of industry working conditions, EMG-derived *spectral entropy*, and *median frequency*, both extracted from time-frequency analysis, and *mobility* extracted from time domain, were the best indicators of the manifestation of muscle fatigue.

- **Keywords:** Biomechanics Entropy Median frequency Time-frequency analysis Shoulder

Laura Johnen, Alexander Mertens, Verena Nitsch & Christopher Brandl. *Why cumulative loading calculated using non-weighted integration may not be suitable for assessing physical stress of the lower back: an empirical investigation of strain during lifting and lowering tasks*. Pages: 134-146.

When work-related physical stress is assessed using non-weighted integration, it is assumed that different loading conditions have a sufficiently comparable effect on the human body as long as the area under the loading curve is the same. Growing evidence cast doubt on whether this simple calculation can adequately estimate physical work-related strain. This study investigates in vivo, focussing on the lower back, whether the non-weighted method adequately reflects work-related physical strain of the lower back. Strain data resulting from lifting/lowering tasks performed in a laboratory study with an identical area under the loading curve but different load intensities were compared. Results showed that the non-weighted method does not sufficiently reflect the resulting muscular, cardiovascular and perceived strain but underestimates the influence of higher load intensity even in the range of medium physical exposure. Further research is needed regarding the determination of weighting factors and limit values. **Practitioner Summary** Given the dynamic nature of most physical work activities, the assessment of time-varying loading of the lower back is of particular interest in practice. Results show

that the widely used non-weighted calculation method does not accurately reflect the resulting physical strain but underestimates the influence of higher load intensity.

- **Keywords:** Cumulative loadingmanual material handling, non-weighted integrationlower back

Christopher J. Gaffney, Jack Cunnington, Kate Rattley, Elizabeth Wrench, Chloe Dyche & Theodoros M. Bampouras. *Weighted vests in CrossFit increase physiological stress during walking and running without changes in spatiotemporal gait parameters*. Pages: 147-158

This study quantified the physiological and biomechanical effects of the 20 lb (9.07 kg, males) and 14 lb (6.35 kg, females) weighted vest used in CrossFit, and whether they were predisposed to injury. Twenty subjects (10 males, 10 females) undertook walking (0%, 5% and 10% gradient) and running trials in two randomised study visits (weighted vest/no weighted vest). Physiological demand during walking was increased with the vest at 10% but not 5% or 0% with no change in gait variables. In the running trial, the weighted vest increased oxygen uptake (males; females) (+0.22L/min, $p < 0.01$; +0.07 L/min, $p < 0.05$), heart rate (+11bpm, $p < 0.01$; +11bpm, $p < 0.05$), carbohydrate oxidation (+0.6 g/min, $p < 0.001$; +0.2 g/min, $p < 0.01$), and energy expenditure (+3.8 kJ/min, $p < 0.001$; +1.5 kJ/min, $p < 0.05$) whilst blood lactate was increased only in males (+0.6 mmol/L, $p < 0.05$). There was no change in stride length or frequency. Weighted vest training increases physiological stress and carbohydrate oxidation without affecting measured gait parameters. **Practitioner summary:** We examined the effect of weighted vest training prescribed in CrossFit (20 lb/9.07 kg, males and 14 lb/6.35 kg, females) in a randomised controlled trial. We found that physiological stress is increased in both sexes, although three-fold greater in males, but with no change in biomechanical gait that predisposes to lower-limb injury.

- **Keywords:** CrossFit, external load, injury, sex-based differences, weighted resistance exercise